Advise^{IT} Asset Sentry

Condition Monitoring Technology Definitions

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1.0 Acoustics

Acoustic detection of partial discharges is very attractive for field diagnosis as the test can be applied under continuous service. Furthermore, due to the low velocity of the acoustic signals, the PD sources may be located thereby giving a better basis for a decision on the appropriate actions. The acoustic signals from partial discharges are usually found around 100 kHz. Discharge sources under insulating materials can have frequencies down to about 50 kHz and be strongly attenuated. It is therefore important that very sensitive acoustic transducers covering the frequency range 50 – 100 kHz are used in the diagnosis. Sensitivity is more important than flat frequency response; therefore piezo-electric acoustic emission sensors are preferred. In a typical transformer installation, several sensors will be affixed to the tank. When a PD source is detected, the source direction can be found using signals from several sensors.

2.0 Battery Test

A battery impedance test set injects an AC signal between the terminals of the battery. The resulting voltage is measured and the impedance then calculated. This measurement can be accomplished without removing the battery from service since the AC signal is low level and "rides" on top of the DC of the battery. Two comparisons are then made: first, the impedance is compared with the last reading for that battery; and second, the reading is compared with other batteries in the same bank. Each battery should be within 10% of the others and 5% of its' last reading. A reading outside of these values indicates a cell problem or capacity loss. If a battery has an internal short, the impedance tends to go to zero; if an open exists, the impedance will approach infinity.

3.0 Breaker Timing

A Breaker Timing Test is a mechanical test that shows the speed and position of breaker contacts before, during, and after an operation. There are two general types of timers in use: digital contact timers, and digital contact and breaker travel analyzers. The digital contact timers are only good for timing contacts where no travel time is required. A digital contact and breaker analyzer measures the contact velocity, travel, over-travel, bounce back, and acceleration to determine the condition of the breaker operating mechanism. A voltage is applied to the breaker contacts and a motion transducer is attached to the operating mechanism. The breaker is then cycled (close and open).

4.0 Dielectric Frequency Response (DFR)

Dielectric frequency response (DFR) is a measurement used to assess the quality of the insulation systems of power transformers. The DFR measurement is similar to the power factor or tan δ measurement, except that it is a series of power factor measurements at multiple frequencies. The advantage of doing the measurement at multiple frequencies is that it provides much more information so that the dielectric parameters of the insulation may be determined. The measurement has proved useful not only in the estimation of moisture in transformers, but also the evaluation of drying processes for transformer insulation. In addition, the analysis

method can be extended to other oil/cellulose insulation systems such as instrument transformers, bushings and cables.

5.0 Dissolved Gas-in-oil Analysis (DGA)

The oil is analyzed for dissolved gases using gas chromatography. The results can reveal many problems internal to oil filled transformers before the problem becomes terminal. As events occur inside a transformer (some of which are normal), gases are liberated into the oil. Specifically, the primary causes of these gases are thermal, mechanical, and electrical stresses in the windings. Consequently, it is important that new oil has a good baseline with no contaminants, especially combustible gases. This test requires drawing a 50cc sample of oil from the transformer using specialized sampling equipment. Dissolved Gas Analysis is recommended for all oil filled transformers.

6.0 EPA Oil Leak

Refers to oil leaks, which are extensive enough to be reported to the EPA. Different utilities have different oil leaks reporting criteria to the EPA.

7.0 Frequency Response Analysis (FRA)

By measuring the transfer function of the transformer, deformations of the windings can be detected, provided that a reference fingerprint of the unit is available. Deformation or changes in geometrical distances of the windings, leads to change in internal capacitances, and thereby a change in the transfer function of the transformer. In practice, an impulse is injected on one side, and the Fourier spectrum is measured of both the impulse and of the response on the other side. The transfer function is calculated by dividing the two spectra. This method requires the transformer to be disconnected from the net. It is one of the more frequently used techniques for this type of diagnosis, but has great uncertainties due to the fact that the result is affected by a large number of factors. A predecessor to FRA is low voltage impulse measurements.

8.0 Degree of Polymerization (DP)

This is a measure of the cellulose chain length. New paper in transformers typically has DPs of 1000 and above; the DP value goes down with aging, and the paper would become darker and more brittle. When a value of ca. 300 is reached, the tensile strength decreases approximately 50% (‘end of life’ per ANSI/IEEE Std. C57.92; however, the unit could function if left undisturbed till DP reaches 100-150 (absolute end of life) when it is very dark and brittle, almost powdery.

9.0 Furan Test

These are intermediate products of thermal degradation of paper, and are liquids. They are typically in the ppb (parts per billion) to ppm (parts per million) levels. Labs usually report five different furanic compounds, but for diagnostic purposes only 2-furfuraldehyde (2-FAL) is considered. Thermal aging would cause the furanic levels to increase. Unusual thermal events and hot spots would create more furans in oil. Oil change would deplete furanic content of oil. 2-FAL is considered fairly stable for long periods. However, the furanic compounds are distributed between paper and oil, so the labs can estimate only those left in oil.

10.0 High Potential Test (HIPOT)

Hi-Pot testing is a high voltage DC test that shows excessive leakage current in equipment. It is also used to verify that insulation systems in new equipment can withstand designed voltage levels. Consequently, it is a good acceptance test for new and repaired electrical transmission and distribution equipment. In repaired equipment, if the leakage current continues to increase at a constant test voltage, this indicates that the repair is not to the proper standard and will probably fail prematurely. For new equipment, if the equipment will not withstand the appropriate test voltage, it indicates that the insulation system or construction method is inadequate for long term service reliability. Since DC Hi-Pot testing is a potentially destructive test, it is a standard acceptance test, especially for new or rewound motors, but normally it is not used for periodic testing.

11.0 Inspection

Inspection and testing technologies are those tests that give results that can be used for acceptance criteria but are not normally used for trending. Most tests in this category can be classified as a go/no-go test, i.e., either the equipment passes or fails the test.

12.0 IR Inspection

Infrared Thermography (IRT) is the application of infrared detection instruments to identify pictures of temperature differences (thermogram). The test instruments used are non-contact, line-of-sight, thermal measurement and imaging systems. Because IRT is a non-contact technique, it is especially attractive for identifying hot and cold spots in energized electrical equipment, large surface areas such as roofs and building walls, and other areas where stand off temperature measurement is necessary.

IRT inspections are identified as either qualitative or quantitative. The quantitative inspection is interested in the accurate measurement of the temperature of the item of interest. The qualitative inspection identifies relative differences, hot and cold spots, and deviations from normal or expected temperature ranges. Qualitative inspections are significantly less time-consuming than quantitative because the thermographer is not concerned with highly accurate temperature measurement. What the thermographer does identify is highly accurate temperature differences between like components. For example, a typical motor control center will supply three-phase power through a circuit breaker and controller to a motor. Current flow through the three-phase circuit should be uniform, which means that the components within the circuit should have similar temperatures, one to the other

IRT can be used to identify improper installation conditions in electrical systems such as transformers, motor control centers, switchgear, switchyards, or power lines. In mechanical systems, IRT can identify blocked flow conditions in heat exchanges, condensers, transformer cooling radiators, and pipes. It can also be used to verify the fluid level in large containers, such as fuel storage tanks, and identify improper installation of refractory in boilers and furnaces.

13.0 Leakage Inductance

This is a traditional method for detecting changes in the winding geometry. As a result of a short circuit, the inner winding has a tendency to decrease in diameter whereas the outer increases.

This leads to a higher leakage flux between the windings and thus the measured leakage reactance.

14.0 Leak Detection

A relatively inexpensive device called an ultrasonic noise detector can be used to locate liquid and gas (pressure and vacuum) leaks. When a fluid or gas moves from a high-pressure region to a low-pressure region it produce ultrasonic noise, due to turbulent flow. The detector translates the ultrasonic noise to the audible range, allowing an inspector to identify the source of the leak. In addition, an ultrasonic noise detector can detect arcing, tracking, and corona in electrical systems. For electrical systems, ultrasonics is often used in conjunction with infrared thermography, since corona occurs in the ultraviolet region of the spectrum. Even though this is a subjective test, i.e., results are not quantifiable, it is recommended for use on compressed gas, steam, and vacuum systems as well as on high voltage electrical components.

15.0 Oil Quality

Similar to lubricating oil analysis, testing is done to confirm that the specified oil is installed and is free from contamination and/or degradation. The tests include Color, Karl Fischer (water in oil), Acidity level (Neutralization Number), Power Factor, Interfacial Tension, and Dielectric Breakdown.

16.0 Operational Checks

Operational checks are performed to ensure that systems and facilities respond to changes in demand per design. For example, changes in outside temperature will affect the percentage of make-up air used by the ventilation system. Furthermore, ventilation systems have different operating modes. For example, in a normal operating configuration dampers and supply and exhaust fans will operate in one mode, but during a fire or heavy atmospheric contamination a different mode will be required.

Operational checks test the functionality of the control systems by varying the inputs (i.e., room temperature and humidity) and observing the response of variable speed drives (air handlers and pumps), flow control valves, chiller load, and ventilation dampers.

17.0 Insulation Power Factor

Power Factor, sometimes referred to as "dissipation factor", is the measure of the power loss through an insulation system to ground. The results are expressed in milliwatts loss and percent. The percent refers to a dimensionless ratio, i.e., the percentage of the resistive current flowing through the insulation to the total current flowing. To measure this value, a known voltage is applied to the insulation and the resulting current and current/voltage phase relationship is measured. This test is non-destructive, will not deteriorate or damage insulation, and is recommended for inclusion in any commissioning program.

18.0 Partial Discharge Analysis (PD)

Partial Discharge Analysis is an on-line technology designed to monitor the condition of insulation in machines, cables and power transformers. A partial discharge is an incomplete, or partial, electrical discharge that occurs between insulation and either other insulation, or a conductor. These discharges create a high frequency signal that PD monitoring systems are designed to detect. PD typically is performed for very large power generation and transmission equipment.

19.0 Relay Test

Functional Test: This process verifies that the protective outputs of the relay (e.g., contact closures) actually operate as intended. This can be accomplished as part of the calibration procedure in most cases, but relay functional testing should be verified according to the maintenance schedule. Periodic functional testing is recommended to ensure the integrity of protection circuits.

Calibration: This process usually includes removal of the relay from service to a test environment. Injecting current and/or voltage into the relay and observing the response according to the manufacture's test procedure verifies the recommended settings. Calibration of electro-mechanical relays is recommended fairly frequently since operating mechanisms can wear and get out of adjustment. Calibration of solid-state and micro-processor-based relays is recommended less frequently since there are fewer ways for them to get out of calibration.

20.0 Insulation Resistance

An Insulation Resistance test is a non-destructive direct current (DC) test used to determine insulation resistance to ground. A DC voltage is applied to the equipment under test, resulting in a small current flow. The test set then calculates the resistance. The insulation resistance is generally accepted as a reliable indication of the presence of contamination or degradation; however, test results vary greatly due to environmental conditions, specifically temperature. Consequently, all readings must be corrected to $20^{o}C$ for comparisons to be accurate.

21.0 SCADA

Supervisory Control and Data Acquisition (SCADA) systems are computer-based, real-time control systems for power and water operations. Since these systems are in operation continuously and are in many ways self-diagnosing, regular maintenance and testing is not necessary except as recommended by the manufacturer. However, circuits that are infrequently used may require periodic functional testing to ensure they will be operational when the need arises.

22.0 SF_6 Leak Detection

Leaks in SF_6 insulated equipment can be detected through the use of an acoustic sensor, which detects the ultrasonic noise generated when a gas from a high-pressure system is released into a low-pressure environment. However, for an elaborate gas-insulated-substation (GIS) installation, it is impossible to detect small leaks. Special cameras have been developed for more efficient detection of small leaks in GIS systems. Leaking gas, although invisible to the human eye, shows up on the camera recording as a stream of black smoke.

23.0 TTR

TTR measures the turns-ratio of a transformer and is mainly used as an acceptance test. It can also be used as a trouble-shooting tool when other electrical tests reveal a possible problem. For acceptance tests, a TTR is performed to identify short-circuited turns, incorrect tap settings, mislabeled terminals, and functional failure in tap changers. To perform a TTR, a voltage is applied to the primary and the induced voltage on the secondary is measured. The ratio is then calculated and compared to the nameplate data. TTR determines if a fault exists, but does not identify the root cause or the location of the fault.